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Geometry and modeling of an active offshore thrust-related fold system: the Amendolara Ridge, Ionian Sea, southern Italy

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On the Ionian Sea coast of southern Italy, spanning the transition from the Calabrian Arc to the Apennines, NE-directed motion of the thin-skinned frontal thrust belt of the Apennines toward the Apulian foreland reportedly ceased during the Early-Middle Pleistocene (PATACCA & SCANDONE, 2007). Deformation since then was dominated by the regional uplift of the Calabrian Arc (WESTAWAY, 1993; CUCCI & CINTI, 1998). However, detailed structural and geomorphologic analysis has revealed that uplift of Middle Pleistocene and younger marine terraces not only ensues from a regional-scale process, but also reflects a smaller-wavelength component of shortening which is attributed to recent, deeper activity of blind thrust and transpressional structures (FERRANTI *et alii*, 2009; CAPUTO *et alii*, 2010). Thus, shortening in this sector of the Apennines may still be ongoing although at a very slow rate and with a subdue morphological signature. The latter limitations have led to the common thinking that this sector of the Apennines is inactive.

The submarine extension of the frontal thrust belt is represented by the Amendolara ridge, which stretches for over 80 km to the SE beneath the Taranto Gulf, the northern embayment of the Ionian Sea (Fig. 1, inset). Although it was suggested, based on existing multichannel seismic profile analysis, that the ridge has grown as a result of transpressional displacement (DEL BEN *et alii*, 2007; FERRANTI *et alii*, 2009), detailed images of the structural architecture as well as robust constraints on the timing of recent deformation were lacking.

High-resolution marine geophysical data collected on the Amendolara ridge during the TEATIOCA_2011 cruise provided unequivocal constraints to assert active fault-related fold growth. Single-channel seismic (sparker) and acoustic CHIRP profiles, corroborated by multibeam mapping and shallow coring, form the novel dataset to constrain the near-bottom evolution. The new data were benchmarked to the crustal geometry by means of interpretation of existing multichannel seismic profiles.

The integrated dataset analysis revealed that the NW-SE trending ridge has grown during Late Pliocene-Quaternary as a result of motion above an array of blind thrusts grouped into the Amendolara Thrust-Fold System

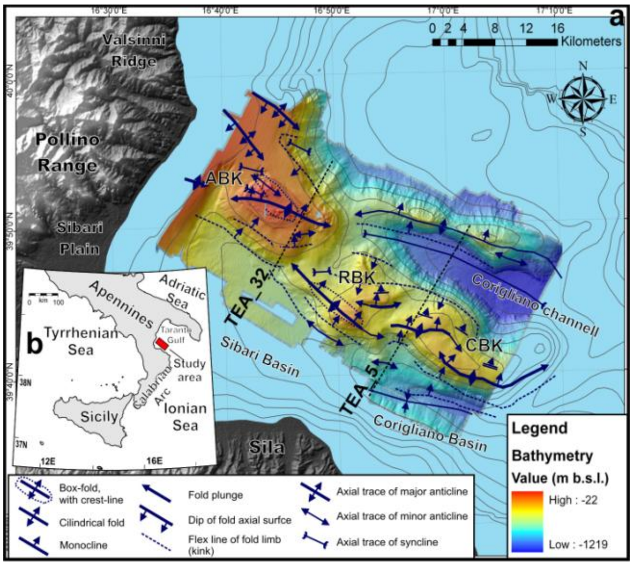

Fig. 1 – Structural map of the Amendolara Ridge based on analysis of Sparker profiles. Base is the multibeam dataset acquired during the TEATIOCA_2011 cruise. Inset b is location of study area. ABK, Amendolara Bank; RBK, Rossano Bank; CBK, Cariati Bank.

(ATFS). Strikingly, the ATFS has displacement to the southwest toward land, and represents a backthrust belt in the regional reference frame.

The stratigraphic signature of recent (Middle-Late Quaternary) fold growth is recorded by syn-tectonic depositional sequences within ponded basins and on the flanks of the ridge, and is represented by tectonically-stacked packages, and by widespread debris flows and slumping (Figs. 2, 3). Along the whole southwest margin of the ridge, the Middle-Late Quaternary depositional packages are ostensibly folded in response to southwest-

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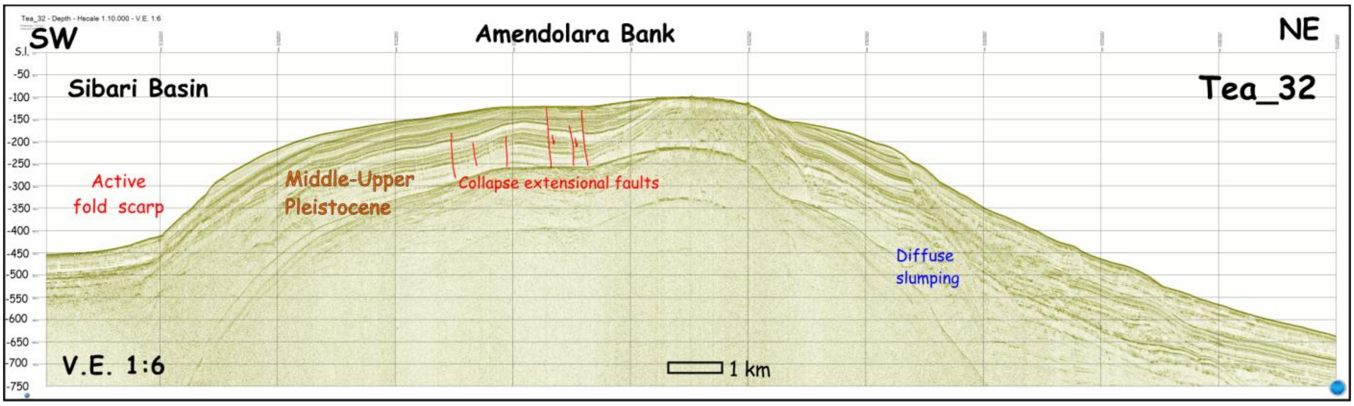

Fig. 2 – Depth-converted line TEA_32 across the Amendolara bank, western part of the Amendolara ridge (location in Fig. 1).

directed displacement, as documented by fold asymmetry (Figs. 2, 3).

Morpho-bathymetry data and seismic profiling show contrasting geometries and structural styles among the three ~15 to 20 km long and right-laterally offset banks which form the top of the Amendolara Ridge (Fig. 1). These banks are floored by the folded sediments and locally by lower Pleistocene or older bedrock. Whereas the Amendolara and Rossano banks are floored by an asymmetric fold (Fig. 2) the structure of the Cariati bank is represented by a north-dipping monocline with a train of minor frontal folds (Fig. 3). Based on the different geometry and morpho-structure, we argue that the banks are the expression of as many en-echelon blind fault segments.

Based on the pattern of folded reflectors, the eastern and central segments (Cariati and Rossano, respectively) display evidence of more recent activity (Fig. 3). To the north of the Amendolara bank , a NE-verging system of two anticlines (Fig. 2), which are the offshore prosecution of the Valsinni ridge on-land (one of the recent most uplifted ridge of the Southern Apennines, PATACCA & SCANDONE, 2007), fold the basal unconformity of the last glacial sequence.

Appraisal of the crustal seismic reflection profiles calibrated with exploratory wells reveals that the ATFS controlled deposition of an up to ~3 km thick syn-tectonic Late Pliocene-Quaternary sedimentary sequence in the Sibari and Corigliano basins, which flanks the ridge to the southwest (Fig. 1).

Numeric modeling of Middle Pleistocene markers extracted from the sparker, and of older markers derived from the multichannel seismic dataset suggests that the three steep blind segments, which are the deep expression of the folded or tilted sediments in the banks, are rooted at ~10 km depth into a low-angle dipping detachment ramp extending to ~20 km depth. This deeper ramp is responsible for the overall NE-tilt of the ridge (Fig. 3) and development of a larger-wavelength fold involving the ridge as a whole.

Documentation of active fold growth beneath the Amendolara Ridge carries important seismotectonic implications. This part of southern Italy is characterized by a low level of historical and instrumental seismicity. Indeed, the region suffered from moderate but locally damaging earthquakes caused by yet unknown or debated sources.

The strongest earthquakes in the area are the 1836, April 25 (M= 6.2), the 1917, June 12, (M=5.25) and the 1988, April 13 (M=5) (data from CPTI11, ROVIDA *et alii*., 2011). The 1917 and 1988 events are located offshore, and our new analysis supports the contention that they spatially coincide with the central-eastern segments of the ATFS, where the evidence of more recent activity is found (Fig. 3). On the other hand, evidences show that the 1836 event is located inland, near the northern coast of the Sila (GALLI *et alii*, 2010). We also investigated the tsunami occurred during the 1836 event (TINTI *et alii*, 2004) and the alternative hypothesis between earthquake or submarine landside.

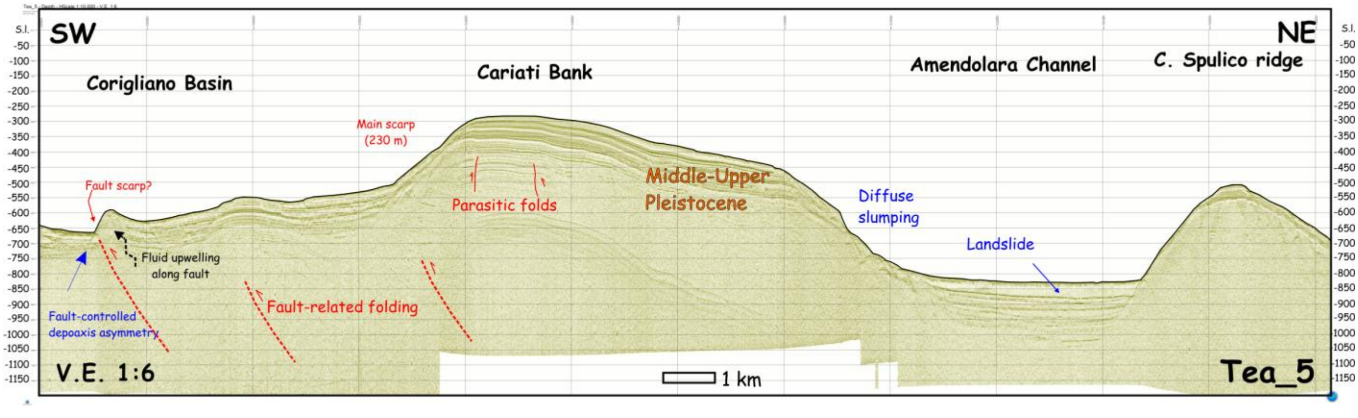

Fig. 3 – Depth-converted line TEA_5 across the Cariati bank, central part of the Amendolara ridge (location in Fig. 1).

Today, the ATFS shows a moderate seismic activity expressed by Mw<4.7 thrust and transpressional earthquakes (Fig. 4), which apparently originate at the branching zone between shallow ramp segments and deep detachment. The incremental shortening axis resolved onto the mean strike of the ATFS indicates left-oblique to reverse motion. Based on the size of fault segments and the modeled depth of micro-seismicity, we argue that the ATFS may be capable of moderate (M~6) earthquakes.

Growth of the Amendolara Ridge temporally coincides with cessation of the Southern Apennines thin-skin thrust belt motion, when collision between southern Adria and Europe overwhelmed retreat of the Apulian-Ionian slab, that had dominated the structural evolution of the central Mediterranean orogen since the Oligocene. The localization of the transpressional belt was controlled by an inherited mechanical interface between the thick Apulian crust and the attenuated Ionian crust.

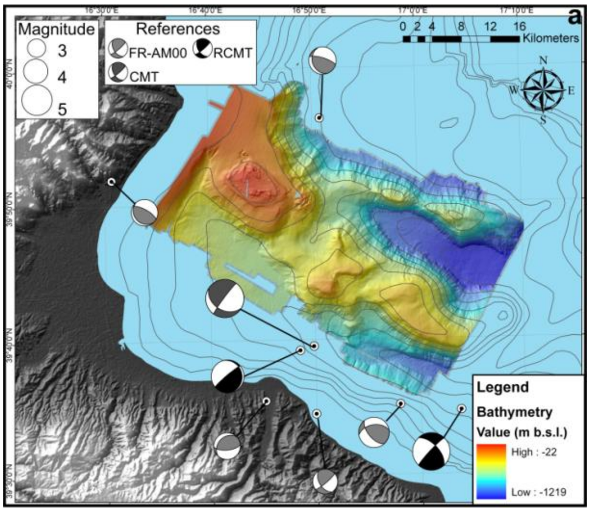

Fig. 4 – Focal solutions in the southern Gulf of Taranto: CMT, arvard CMT catalogue; FR-AM00, Frepoli and Amato [2000]; RCMT, European-Mediterranean RCMT catalogue.

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